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Tensile Characterization of Novel Fiber Metal Laminate (FML) using Copper/Brass Sheets and Kevlar/Carbon fibers

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Abstract: In this research article the tensile characteristics of the novel fiber metal laminate made with copper (CU), brass (CU) sheets Kevlar (K) and carbon (C) fibers as the reinforcement with 0, 0.5 and 1 wt. % of carbon nanotubes (CNTs) in an epoxy material is studied with three different stacking sequences.CNTs is mixed with epoxy resin LY556 and HY951 hardener using a ultrasonicator. The Resin and hardener are taken in the ratio of 10:1. The composite laminate is fabricated by hand lay-up method. Compression moulding is used to compress the fabricated composite. After fabrication the composite laminate is cut into required dimension as per ASTM standard D638.Tensile test is performed on the composite laminate using a Universal Testing Machine (UTM) with a elongation speed of 2mm/min and corresponding tensile strength, stress strain values are noted. Finally, the failure of the specimen is studied using Scanning Electron Microscopy (SEM) images.

***Index Terms*: Copper, Brass, Kevlar, Carbon, SEM**

I. INTRODUCTION

Fiber metal laminate FML are hybrid composite materials having fiber and metals generally in the form of metal sheet are used as the reinforcement in a common matrix material. This type of materials are superior in their characteristics compared with original constituent materials.it has the advantages of fibers and sheet metals. The limitations of each materials is minimized by combining them. Commercially available FML's including Carbon Aluminum Reinforced Laminate (CARALL), Aramid Reinforced Aluminum Laminate (ARALL), Glass Aluminum Reinforced Laminate (GLARE) are used in most of the automobile, aerospace applications and manufacturing of structural applications because of their weight saving nature and enhanced mechanical properties [1]. Light weight components made up with FMLs resulted in more fuel efficient in aerospace and automobile industries. In addition to it FML's are corrosion resistance, having high specific strength. Generally Aluminum based metals are used as the reinforcement in the FMLs [2-5].Various types of reinforcement, fibers and filler materials are investigated by researchers [1-10]. An attempt has been made to use Copper, Brass sheets as reinforcement along with carbon and Kevlar fibers in a common matrix material having certain percentage of Carbon nanotubes (CNT's) dispersed in them.

The present research work aims to study the mechanical behavior of FML made up with three different stacking sequences having three different propositions of Carbon nanotubes (CNT) i.e. 0%, 0.5% and 1%. The stacking sequences used in this fabrication process are shown in the table 1.

Table 1. Stacking sequences of the laminate

Specimen No	Stacking Sequences	Wt.% of CNT
1	Cu/Ca/Ca/Br/Ca/Ca/Cu	0
2	Br/K/Cu/Ca/Cu/K/Br	0.5
3	Cu/Ca/K/Br/Ca/K/Cu	1

Reinforcement used in this research are Carbon and Kevlar fibers along with copper and brass sheets. Epoxy resin LY556 and hardener HY951 are used as the matrix material. CNT is used as the filler material.

II. MATERIALS USED

The reinforcement materials like carbon and Kevlar fibers along with resin LY556 and Hardener HY 951 are purchased from Go Green products, Chennai. The remaining metal sheets of copper, brass are brought in Ambattur Industrial Estate, Chennai. Carbon Nanotubes (CNT's) with a purity of 99.98% is brought from Mumbai. The properties of the materials are shown in the table2.

Table 2.Properties of Materials

Properties	Copper sheet	Carbon fiber	Brass sheet	Kevlar fiber
Density (g/cm^3)	8.96	2.26	8.73	1.44
Poisson's Ratio	0.33	0.26	0.34	0.35
Hardness (VHN)	2.5	10.0	92	-
Melting Temperature (°C)	1085	3550	940	500
Tensile Strength (MPa)	200	228000	345	3620

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III. STACKING SEQUENCE

Stacking the layers of fibers and metal sheets in the composite laminate plays a key role in determining the properties of the composite that has been fabricated [2].

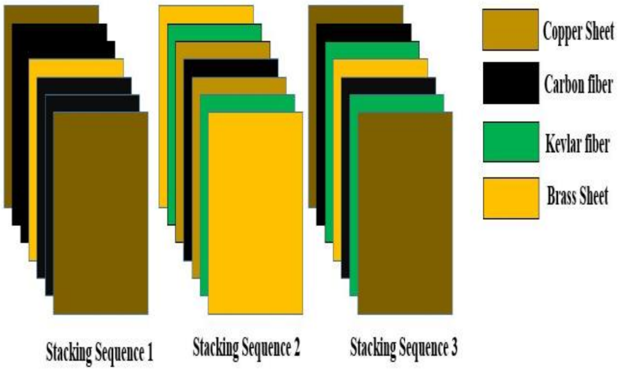

Fig.1. Stacking sequences

Three different stacking sequences used in this research is shown in the figure 1.

IV. FABRICATING METHOD

Hand lay-up is method adopted in fabricating the FML's. The epoxy resin and hardener are mixed in a ratio of 10:1 [2]. CNT's with different wt. % are mixed in resin mixture with help of ultrasonicator for uniform dispersion of CNT in the resin mixture. A mould of suitable size of 300 mm x 300 mm is chosen and a releasing agent is applied on the top plate and bottom plate surface of the mould to access the finished composite laminate. The reinforcement sheets and fibers are cut into the dimension of the mould. The metal sheets are scrubbed with emery sheet to ensure good bonding [2].First layer of the CNT mixed resin mixture is poured on the coated mould and a brush is used to spread the mixture throughout the mould surface later the first layer of the first stacking sequence i.e. Copper sheet is placed on the resin mixture and a roller is pressed by hand to apply a pressure on the sheet. Then, the sheet is coated with second coat of resin mixture. Again the next layer of carbon fiber is placed on the resin mixture and once again the procedure is followed to complete the fabrication of first sequence of the composite laminate. The fabricated composite laminate are compressed with a help of compression moulding machine at a 70 bar pressure for about twenty minutes to remove the excess resin and air bubbles entrapped with the layers of the composite. Once the fabricated composite laminate is removed from the compression moulding machine it is allowed to cool down at room temperature. Later on, the composite laminate is cut into required dimension as per the testing standards of ASTM.

V. TENSILE TEST

Tensile test of the composite laminate are done as per the ASTM standard D638. The specimens are cut into dog bone shape as shown in figure 2.

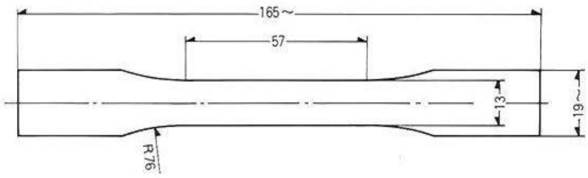

Fig.2. Schematic diagram of tensile specimen

The test is performed using a Universal Testing Machine (UTM) which is having a capacity of 10 kN. Test done at a room temperature. Specimens are fitted in the upper and lower jaw of the tensile testing machine and the specimen are tested with a uniform cross head speed of 2mm/min. The test is carried out until specimen fails. The tensile tested specimens 1,2 and are shown in the figure 3 a, b and c.

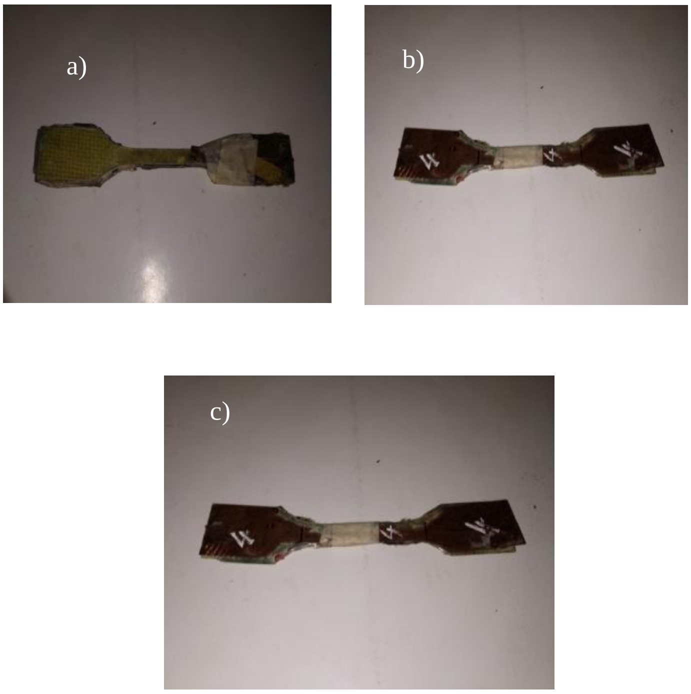

Fig.3. Tensile tested specimen

The corresponding stress strain graph is obtained directly from the machine as shown in figure 4,5 and 6.

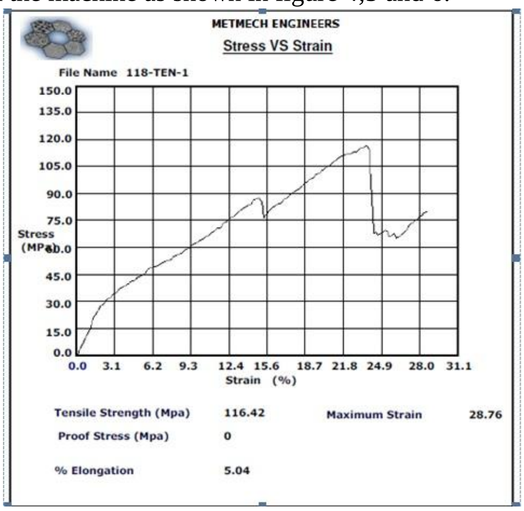

Fig.4. Specimen 1 Stress Vs Strain graph

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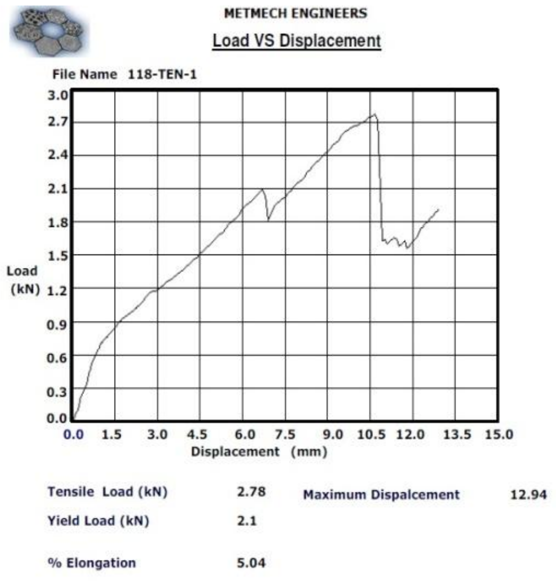

Fig.5. Specimen 1 Stress Vs Strain graph

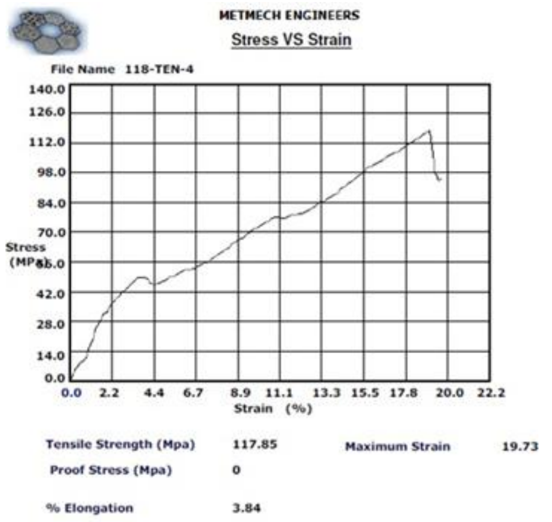

Fig.6. Specimen 1 Stress Vs Strain graph

The composite laminate made with three different stacking sequences are tested for the tensile strength and corresponding values are obtained. The specimen 1 which is made up of upper most layers with copper sheet has the tensile stress of 116.42 MPa and a maximum strain of 28.76%. It can take a maximum tensile load of 2.8kN and displacement of about 12.94 mm. the composite specimen 2 with outer brass sheets take a maximum tensile load of 2.8 kN and displacement of 8.88 mm. the tensile stress is also about 117.85%. The third specimen of carbon fibers as the outer layer has the least ultimate stress of 91.33 MPa comparing with other two specimens. The specimen 3 also has the lowest displacement of 5.63mm. Tensile test results of the specimens are tabulated in the table 3.

Table 3. . Tensile test results of the specimens

Specimen No	Breaking Load (kN)	Max. Disp. (mm)	Ultimate Tensile Stress (MPa)
1	2.8	12.94	116.42
2	2.8	8.88	117.85
3	2.74	5.63	91.33

It is very vivid from test results that the specimen made with sheet metals as the outer layer can take comparatively higher tensile load than the specimen made carbon fibers as the outer layers [2]. Addition of CNTs at 0.5 wt. % is more effective on the composite laminates than adding of 1 wt. % of CNT to it. The specimen 1 with 0 wt. % of CNT has ultimate tensile stress nearly equal to specimen 2. It clearly indicates that adding CNTs to metal reinforced laminates has less influence in increasing the properties of the composites.

VI. SEM

Tensile test specimens are studied with the help of Scanning Electron Microscopy (SEM) images to know the nature of failure of FMLs. SEM is obtained using SEM instrument by applying 10 kV current.

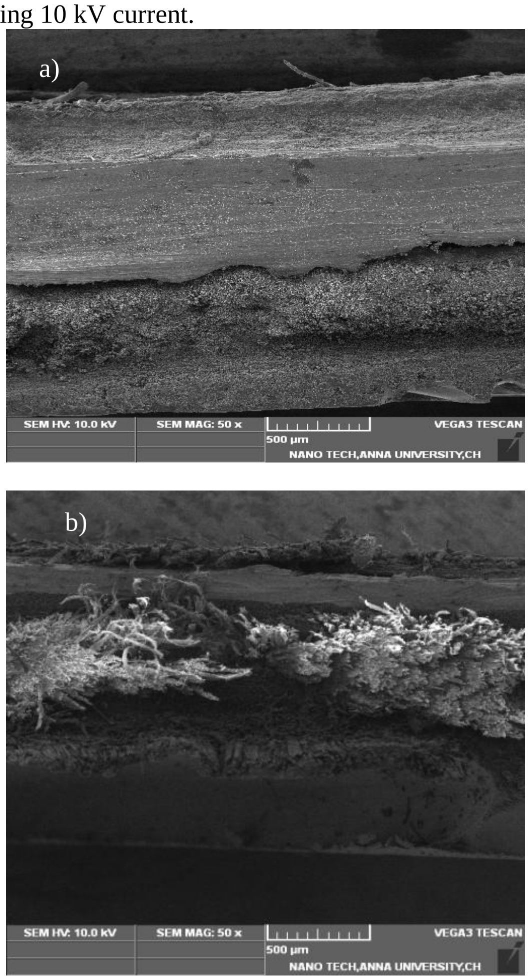

Fig.7. SEM image of tensile test specimen

SEM images of the tensile tested composites are shown in the figure 7 a and b.

The SEM images shows that

There is poor bonding between the metal layers and fiber layers. Moreover, dispersion of CNTs in the matrix is improper. It is not uniformly distributed and it can be seen in the images that CNTs are settled like a pile on the metal layers. The failure of the composite is due to delamination of the metal layers, followed by matrix and fiber failure.

VII. CONCLUSION

In this research a novel fiber metal laminate reinforced with a combination of metals sheets and fibers and also with varying wt. % of CNTs are tested for their tensile properties as per ASTM D638. The test result concludes that the addition of CNTs has no or less influence on the tensile properties.it may be due to improper of dispersion of the CNTs in the resin matrix. SEM images conclude the same observations. It is also noted that it is difficult for the CNT filler material to distribute on the metal surfaces resulting in poor bonding between the layers.

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